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FERVANITE, A HYDROUS FERRIC VANADATE

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SUMMARY

A hydrous ferric vanadate from the carnotite region of Colorado and Utah is described. The formula is $2Fe_2O_3 \cdot 2V_2O_5 \cdot 5H_2O$ and the mineral has been named fervanite from the metallic elements contained, iron (ferrum) and vanadium.

OCCURRENCE (F.L.H.)

The area covered by southwestern Colorado and southeastern Utah, in which the largest known deposits of carnotite and accompanying minerals are found, is semi-arid, and as in most such regions veinlets and crystals of gypsum are common. The gypsum is often found containing inclusions of carnotite.

Practically all of the uranium and vanadium minerals of these deposits, like the gypsum, have been formed from cool meteoric water circulating through the comparatively soft porous McElmo sandstones. The original uranium and vanadium minerals, whatever they may have been, all have been re-worked and moved a greater or less distance from their original positions. This re-working of the minerals, which is plainly still in process, has led to a number of new combinations, owing to the very complex chemical affinities of vanadium. The carnotite ores are never simple but are a confused mixture of minerals. However, segregation takes place in certain localities so that here and there comparatively pure specimens of one or more of the various minerals can be obtained.

While working with these mineral aggregates a nearly transparent fibrous brownish to yellow mineral was frequently noticed. This resembled satinspar colored by a little carnotite, and as selenite is found containing distinctly visible inclusions of carnotite it seemed probable that the yellowish or brown fibers were satinspar colored by carnotite.

[1] Published by permission of the Secretary of the Smithsonian Institution.

However, a few years ago better material was collected (by F.L.H.) on Polar Mesa on the north side of the La Sal Mountains, Grand Co., Utah, and later Mr. H. H. Christy of Grand Junction, Colorado, sent in a specimen of this material which was so evidently free from carnotite that it could no longer be supposed to be discolored gypsum. Material was also collected (by F.L.H.) in Gypsum Valley, San Miguel Co., Colorado, and it was from this material that the sample was taken for analysis.

Like the other uranium and vanadium minerals of the carnotite region this mineral is one which has evidently formed in place from meteoric water solutions. It occurs with selenite, carnotite, hewettite (or meta-hewettite) and the black vanadium minerals of the carnotite beds. Since having determined it as a mineral we find it in many specimens from the region, and it can undoubtedly be found in many localities from which we have not yet seen it. At certain places it will no doubt form a ponderable part of the vanadium-bearing minerals.

Physical Properties. (E.P.H.)

All the specimens of fervanite so far examined have a uniform golden-brown color and possess a brilliant luster. The fibers are parallel and generally about half a centimeter long. No cleavage is apparent. The specific gravity was not determined because there was not enough material available to use the pycnometer method and a shredded fibrous mass of this type would in all probability retain air which would make the use of heavy solutions impractical.

The optical properties as determined by C. S. Ross are: Indices, $\alpha=2.186$; $\beta=2.222$; $\gamma=2.224$; all ± 0.005, birefringence $=0.038$; extinction slightly inclined to the length of the fiber; optical character, $-$; 2V very small. The mineral is probably monoclinic.

The X-ray photograph was taken by E. Posnjak, and Fig. 1 shows the spacings and estimated relative intensities of the lines observed on the film.

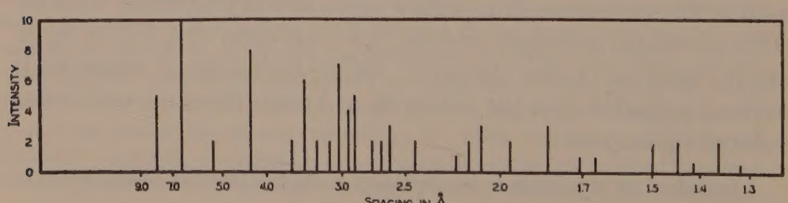

Fig. 1. X-ray Powder Diffraction Pattern.

CHEMISTRY

Fervanite is apparently insoluble in water but no solubility determinations were made because of the limited quantity of material available.

The chemical analysis was made upon a very small, but carefully hand-picked sample obtained from several specimens, and in most cases it was so intimately mixed with other vanadium minerals that only a few milligrams of fervanite could be secured from each specimen. Less than 0.3 gram of suitable material was obtained and the following analysis was made upon a 0.15 gram sample.

ANALYSIS OF FERVANITE
E. P. HENDERSON, Analyst

	Analysis	Insoluble and gypsum	Fervanite		Molecular ratios
			Remainder	Recalculated to 100 per cent	
Insol.	9.40	9.40			
Fe_2O_3	34.46		34.46	41.89	.2597 or 2×.1298
V_2O_5	37.92		37.92	46.10	.2534 or 2×.1267
H_2O-	11.40	1.52	9.88	12.01	.6687 or 5×.1337
CaO	2.40	2.40			
SO_3	3.42[a]	3.42			
	99.00	16.74	82.26	100.00	

[a] Qualitative tests showed SO_3 to be present, and 3.42 per cent is the calculated quantity necessary to combine with the 2.40 per cent CaO present to form gypsum.

The molecular ratios indicate that the chemical formula is $2Fe_2O_3 \cdot 2V_2O_5 \cdot 5H_2O$ and the theoretical percentage composition is 41.30% Fe_2O_3, 47.04% V_2O_5 and 11.64% H_2O.

More than twenty years ago Hewett[2] described a dark greenish black vanadium mineral which laid below a brownish-red to red surface deposit of vanadium oxide in the Quisque District, Peru. He describes this material as "having a greenish black color . . . . The mineral is generally amorphous, though along openings or water-courses it appears velvety, which appearance under the microscope is resolved into aggregates of acicular crystals . . . .

[2] Hewett, D. F., Vanadium Deposits in Peru: *Trans. A. I. M. E.*, vol. 40, p. 274, 1909.

Specific gravity is 2.52." Hillebrand[3] analyzed the material, obtaining the following result:

A VANADIUM BEARING MATERIAL FROM QUISQUE DISTRICT, PERU
W. F. HILLEBRAND, Analyst

V_2O_5	57.33
V_2O_4	4.76
MoO_3	3.28
SiO_2	0.57
TiO_2	0.07
Fe_2O_3	19.53
CaO	0.70
MgO	trace
H_2O	13.89
	100.13

In a later article[4] Hillebrand refers to the material as a mixture, but says that "some of the specimens are characterized by high

A DARK BROWN TO BLACK VANADIUM MINERAL FROM GYPSUM VALLEY, COLORADO
W. T. SCHALLER, Analyst

	Analysis	Recalculated, Insol. and sol. SiO_2 and Al_2O_3 deducted		Ratios	
Insol. SiO_2	9.93				
Sol. SiO_2	2.13				
MoO_3	Not det.				
CaO	0.06		0.07	.0013	
UO_3	0.30		0.35	.0012	
Al_2O_3	1.26				
Fe_2O_3	12.97		15.09	.0944	1
V_2O_4	3.73	V_2O_5	69.46	.3818	4.04
V_2O_5	55.63				
H_2O	12.92		15.03	.8350	8.84
Alkalies	Not det.				
SO_3	Not det.		100.00		
	98.93				

[3] Hewett, *loc. cit.*, p. 294.
[4] Hillebrand, W. F., Merwin, H. E. and Wright, F. E., Hewettite, metahewettite and pascoeite, hydrous calcium vanadates: *Proc. Am. Phil. Soc.*, vol. 53, p. 33, 1914.

iron content and relative freedom from lime . . . which seems to represent essentially a ferric vanadate."

W. T. Schaller, in 1926, made several analyses of vanadium minerals (collected by F.L.H.) from Gypsum Valley, Colorado. The above analysis made by him on a dark brown to black substance has not hitherto been published. If the V_2O_4 is not considered as reduced V_2O_5 the ratios are slightly different but not sufficient to make significant change in the molecular ratios.

The material which Schaller analyzed is very fine grained and almost opaque, but when examined microscopically it appears to be uniform. Nevertheless the nature of the material would hardly justify its being classified as a distinct mineral. The analysis, as shown above, reduces approximately to the following formula: $Fe_2O_3 \cdot 4V_2O_5 \cdot 9H_2O$, but this fact alone is not sufficient to prove the existence of such a chemical compound.

The two above listed analyses contain the highest percentages of iron that have been found in any of the analyzed vanadium minerals, but from the descriptions of the substances and their analyses it is unlikely that either Hillebrand or Schaller had fervanite.

QUARTZ DIKES*

Carl Tolman, *Washington University.*

CONTENTS

Introduction

General Statement

This paper is a review of the available literature concerning quartz masses that are thought by the investigators or other persons to be of igneous origin. The literature relating to this subject appears, on the whole, to be very indefinite in character. In all but a few cases the occurrences are referred to in the most general terms; accurate and detailed descriptions of geological relations are rare, and quantitative data are practically absent.

The Problem

Are there quartz dikes? If so, what is the manner of their occurrence? It is obvious that a pure silica magma would not be possible. The melt would be of a highly viscous nature and would have a high temperature of consolidation, namely 1713°C. due to the lack of other constituents whose presence would cause a mutual lowering of the melting point. There is no evidence of such a high

* The literature of the subject was first examined at the suggestion of Dr. Adolph Knopf. Recently more work has been done and the results are presented in this paper.

temperature at the time of emplacement. It follows then that any quartz mass of igneous origin either contains some mineralogical or fluid impurities or the impurities that must have been present in the quartz magma were of sufficient mobility, such as water, to have escaped at the time of consolidation.

It has therefore appeared profitable to review the literature on quartz masses and ascertain if there are any features in their mineral composition or manner of occurrence that might be of diagnostic value in interpreting their origin.

General Features of Supposed Igneous Quartz Masses

Geological Mode of Occurrence

Quartz masses of supposed igneous origin most commonly described are those in which the quartz mass is gradational from a normal igneous rock. Such gradations are in most cases from pegmatitic or aplitic types but may be from granites or alaskite. The pegmatites showing gradation to quartz masses are, in most cases, associated with acidic rocks. Miller[1] describes a small body of quartz which grades into a pegmatite associated with a gabbro.

The gradation of the igneous rock into the quartz mass may be effected by the appearance of random distributed "blotches" or segregations of quartz which gradually increase in size and number at the expense of the other constituents of the igneous rock until the whole mass is composed of quartz. Other instances have been noted in which the quartz tends to become segregated toward the center of the mass, with bands of feldspar and other constituents following the walls, the transition being brought about by the increase in width of the quartz at the expense of the feldspar and other constituents until it fills the whole space.

Such gradation of igneous rock into quartz masses may occur at the margin of a large igneous body,[2] in dikes, in lens-like bodies traversing the parent igneous rock, or in lenses and dikes traversing slates or schists which constitute the country rock of a granitic in-

[1] Miller, W. J., Pegmatite, Silexite, and Aplite of Northern New York. *Jour. Geol.*, vol. **27**, p. 53, 1919.

[2] Emerson, B. K., Northfieldite, Pegmatite, and Pegmatite Schist. *Amer. Jour. Sci.*, vol. **40**, pp. 212–217, 1915.

Hall, A. L., Note on Certain Wide-spread Ultra Acid Rocks Occurring along the Margin of the Bushveldt Granite in Western Secucuniland. *Trans. Geol. Soc., S. A.*, vol. **13**, p. 10, 1911.

Dwerryhouse, A. R., Intrusive Rocks in the Neighborhood of Eskdale. *Q. J. G. S.*, **LXV**, p. 64, 1909.

trusion. Quartz masses of the latter type occur in shapes ranging from sharply defined tabular bodies to narrower and more irregular lenses and vary in width from a fraction of an inch to many feet. In most places the quartz bodies are parallel to the structure of the enclosing rock but some of the smaller bodies may cut across. Such dike-like or lens-like bodies may extend across the contact and occur in both granitic and surrounding metamorphic rock. The gradation to quartz masses occurring at the margin of large igneous bodies may be evident only at certain localities along the margin.

Among the dikes peripheral to an intrusive mass, it has been noted in places that the acidity of the rock increases with the distance from the parent igneous mass until the dike is composed wholly of quartz which in turn may finally gradually take on crustification and other characters of vein formations.[3]

Accompanying bodies of quartz showing gradation into igneous rock, there may be other quartz bodies showing no such relation though similar in all other respects.

Masses of granite, pegmatite and aplite, grading into quartz and all occurring as lenses or dike-like masses, have been formed in gneissic granite with which they are believed to be genetically connected.[4] Some have sharp and others have gradational contacts with the enclosing rock. Primary gneissic structure of the gneiss is described as bending around the quartz and pegmatitic masses. This is interpreted to mean that the quartz and pegmatitic masses were early crystallized segregations surrounded by the bulk of the magma which underwent further movement during crystallization. In places the quartz and pegmatitic masses are described as having been broken up into lenses by this movement and these aligned parallel to the cleavage of the gneiss. There are later masses of pegmatite and quartz, of which many cut across the structure of the gneiss.

Quartz bodies with some variation in structural, textural, and mineralogical characters are described as occurring in the country

[3] Van Hise, C. R., Principles of Pre-Cambrian North American Geology. *16th Cent. Rept. U. S. G. S.*, pt. **1**, p. 638, 1896.

Billingsley, Paul, The Boulder Batholith of Montana. *Trans. Amer. Inst. Min. & Met. Eng.*, vol. **51**, p. 43, 1915.

Butler, B. S., The Ore Deposits of Utah. *U. S. G. S., P. P.*, **111**, p. 159, 1920.

Lahee, F. H. Metamorphism and Geological Structure. *Am. Jour. Sci.*, vol. **33**, p. 463, 1912.

[4] Miller, W. J., Pegmatite, Silexite, and Aplite of Northern New York. *Jour. Geol.*, vol. **27**, pp. 28–54, 1919.

rock adjoining a granite intrusion into which they show no apparent gradation but which are thought to be igneous because of contact effects.[5] These range up to 20 cms. in width and tend to follow the schistosity when occurring in schists.

Many vein-like quartz bodies, containing metallic ores, as well as some other types of ore bodies are held by J. E. Spurr and others to be vein dikes, on the ground that the solutions from which the bodies were formed are more akin to intrusive ore magmas than to relatively fluid vein-forming solutions. Since pegmatites, aplites and vein-forming solutions of magmatic origin are all regarded as differentiation products of a consolidating parent magma and since transitions from pegmatites and aplites to quartz bodies, some of which carry metallic minerals, are known, Spurr prefers to designate as vein dikes, not only the quartz bodies showing such gradation into normal igneous rocks, but also certain other similar quartz-metallic bodies. These have no such gradational relation but show features that are interpreted by him to indicate that the solution responsible for the body was relatively viscous or had other characters more to be expected in a magma than in a fluid vein-forming solution.

Many people find it very hard or impossible to explain certain features in connection with those quartz metallic ore bodies designated by Spurr as vein dikes if the ore magma, which on consolidation formed the vein dike, had the same features generally attributed to magmas and did not partake largely of the nature of a vein forming solution. Much controversy has resulted and considerable discussion of this question is to be found in the literature. The writer will largely confine his treatment to the discussion of quartz masses of supposed igneous origin that are not metallic ore bodies.

Time Relation to Dike Retinue

Most of the so-called quartz dikes which have been described are probably siliceous variants of pegmatitic or aplitic intrusions and as such are part of the latest igneous manifestation in an epoch of igneous activity. They thus constitute the siliceous residuum of a differentiating magma forced out of the magma chamber after the bulk of the magma had consolidated. However, in places, lampro-

[5] Baumgärtel, B., Eruptive Quarzgänge in der Umgebung der vogtländisch-westerzgebirgischen Granitmassive. *Zeit. d. deut. geol. Ges.*, vol. **63**, p. 175 et. seq., 1911.

phyre dikes cut pegmatitic, aplitic and quartz veins of the same igneous epoch and accordingly lamprophyre dikes are described as being contemporaneous with or cutting quartz-metallic veins or the vein dikes of some authors.[6] In most occurrences of other types of quartz masses of supposed igneous origin that have come to the notice of the writer, their relation to dikes of the same intrusive epoch is not brought out. Miller[7] describes two ages of pegmatite and related quartz masses believed of the same intrusive epoch. Baumgärtel[8] describes supposed igneous quartz masses cut by later quartz bodies thought to represent a hydrothermal phase of the same igneous epoch.

Texture and Structure

The quartz masses under discussion typically exhibit a granitic texture similar to that of normal igneous rocks. Druse-like cavities have been described. More or less banding may be present where an arrangement of the different mineral constituents in separate zones parallel to the walls forms a gradual gradation into pegmatites. Definite crustification in the filling of a fissure is generally held to be the result of vein-forming conditions.

Mineral Composition

Quartz masses of possible igneous origin commonly resemble pegmatites in mineral composition. Many of them differ from pegmatites only in the relative proportions of the different minerals. Described occurrences of probable igneous quartz masses of extreme purity are rare. Among the common minerals, one might mention orthoclase, microcline, albite, microperthite, tourmaline, muscovite, biotite and garnet.

Criteria for the Recognition of Quartz Dikes

Gradation of Quartz Masses into Rocks of Igneous Origin

In the literature a considerable number of instances are mentioned in which quartz masses grade outward from igneous bodies such as pegmatites, aplites, and alaskites and it is assumed because of this relation that the quartz masses are igneous. This does not

[6] Spurr, J. E., Basic Dike Injection in Magmatic Vein Sequences. *Bull. Geol. Soc. Am.*, vol. **36**, pp. 545–582, 1925.

[7] Miller, W. J., Pegmatite, Silexite, and Aplite of Northern New York. *Jour. Geol.*, vol. **27**, p. 28, 1919.

[8] Baumgärtel, B., Eruptive Quarzgänge in der Umgebung der vogtländisch-westerzgebirgischen Granitmassive. *Zeit. d. deut. geol. Ges.*, vol. **63**, pp. 175–239, 1911.

necessarily follow. According to the generally accepted scheme of the evolution of igneous rocks the different varieties are evolved through fractional crystallization of a magma and a settling out of the crystals. In the natural course of events, as the consolidation of the magma proceeds the salic and more volatile constituents tend to be concentrated in the unconsolidated portion. This represents the material that goes to form the salic rocks, pegmatites, aplites, alaskites, as well as quartz masses and veins, and other vein materials of igneous derivation. Thus, in accordance with this theory, there could well be a complete gradation from an igneous mass into veins of hydrothermal origin.

Similarly, the contrary argument—that because quartz masses grade into such rocks as pegmatites, aplites, and alaskites, the latter are hydrothermal in origin—is equally invalid. The whole question of the origin of these rocks is involved and there is here no complete unanimity of opinion. It is not the writer's purpose to discuss the origin of pegmatites, aplites, and similar rocks. It might be safely said, however, that it is generally held that the majority of such rocks represent the solidification of a magma which at times, at least, was of highly aqueous nature.

It is seen then that the existence of a gradation from igneous rock into nearly pure quartz masses is not proof that the latter represents a solidified magma. To be sure such a relation indicates an igneous derivation, but the quartz mass could quite well be a quartz vein, *i.e.*, be deposited from a solution representing the salic concentrate attending magma consolidation.

On the one hand there are undoubted igneous rocks such as granite, alaskites, and some pegmatites and aplites at least, which may be exceptionally high in silica, and there are also quartz veins whose origin cannot be questioned. Quartz masses of some kind therefore appear to bridge the gap between igneous rocks and hydrothermal veins of igneous derivation. If there exists a natural gradation, as there appears to be, between igneous rocks with increasing quartz content and quartz veins, obviously, any boundary which we assume between these two occurrences must be an arbitrary one.

Texture

Veins commonly show the normal granitic texture of igneous rocks; crustification, though indicative of vein formation is usually absent. Vein banding due to the deposition of successive layers of

material of different composition can be simulated in igneous rocks, for instance, in primary gneisses. Some pegmatite dikes, perhaps of doubtful igneous origin, show banding of constituents.

Mineral Composition

Not all igneous rock minerals are recognized as vein-forming minerals. This suggests a possibility that some of the minerals present in quartz dikes might be of diagnostic value.

Contact Phenomena

Igneous rocks characteristically contact metamorphose the rocks which they intrude. They also cause hydrothermal alteration by the loss of fluid constituents on consolidation. Since vein-forming solutions are formed as an end product of magmatic consolidation they would have a relatively low temperature, so that under normal conditions contact metamorphism would not be expected. Hydrothermal alteration would, however, be especially characteristic. The character of the contact alteration, therefore, might serve as a criterion.

Mode of Emplacement

A highly quartzose magma would be extremely viscous. It would be expected that such a magma, in some cases, would intrude itself laccolithically. Such structures as schistosity may tend to form in the intruded rock and would be likely to wrap around it. This might be a valuable criterion but care would have to be exercised in distinguishing such relations from those caused by movement later than the formation of the quartz masses; a weak country rock might be deformed and schistosity developed, which would envelope the more resistant and consequently undeformed quartz masses.

Unsupported Inclusions

The presence of unsupported inclusions in veins has been considered by some as conclusive evidence that the vein material represented a consolidated igneous magma; the argument being that hydrothermal solutions would not have sufficient density to support them. Such, however, cannot be considered as an absolute criterion. It has been pointed out that such fragments might be pried from the walls by the force of crystallization. It is also thought by some that the vein material in some cases at least was carried in colloidal solution or gel; such a solution might be of sufficient density to suspend fragments of the wall rock. Further, it is con-

ceivable that replacement might sometimes act so as to produce fragments that would give the appearance of being unsupported.

Occurrences

Those Showing Actual Gradations into Igneous Rocks

In the Pyrennes, F. Zirkel[9] early noted feldspar-quartz masses in many places grading into masses consisting only of quartz. Credner[10] found similar relations in Saxony. The same observations were made by Lehman[11] who found that the gradation of quartz masses into pegmatites took place in most places by means of the appearance of feldspar, tourmaline, or mica crystals.

Auriferous quartz veins and quartz veins believed to be of pegmatitic origin were observed at Dargo and Omeo, Victoria, Australia.[12] The quartz veins classed as pegmatitic in places take on the appearance of pegmatites through the presence of varying amounts of feldspar, muscovite and tourmaline, singly or severally. Brögger[13] acknowledged the transition between quartz veins and pegmatites and pointed out the importance of mineralizers in their formation. Sederholm[14] describes small pegmatite masses composed of quartz and feldspar which grade into quartz dikes. He believes the pegmatite and quartz represents the final residue of the Rapakiwi magma probably rich in water and other mineralizers and so crystallized slowly. Klemm[15] refers to quartz lenses and veins, in a mica-rich gneiss, grading into pegmatite by the coming in of feldspar and light-colored mica. Williams[16] in considering the pegmatites of Maryland describes quartz masses with pegmatitic associations

[9] Zirkel, F., Beiträge zur Geologischen Kenntnis der Pyrenäen. *Zeit. d. deut. geol. Ges.*, vol. **19**, p. 105, 1867.

[10] Credner, H., Die granitischen Gänge des sachsischen Granulitgebirges. *Zeit. d. deut. geol. Ges.*, vol. **27**, p. 176, 1875.

[11] Lehman, L., Die Enstehung der Altkrystallinischen Schiefergesteine. *Bonn*, **1884.**

[12] Howitt, A. W., Notes on the Area of Intrusive Rocks at Dargo. *Trans. Roy. Soc. of Victoria*, vol. **23**, 152, 1887. Notes on the Metamorphic Rocks of Omeo. *Trans. Roy. Soc. Victoria*, vol. **24**, 1888.

[13] Brögger, W. C., Die Mineralien der Syenitpegmatitgänge der südnorwegischen Augite und Nephelinsyenite. *Zeit. für Kryst. und Min.*, vol. **16**, pp. 226, et. seq. 1890.

[14] Sederholm J. J., Über die finländischen Rapakiwigesteine, *Tschermaks Min.-Petr. Mitteil.*, vol. **12**, p. 8, 1891.

[15] Klemm, G., Beiträge zur Kenntnis des krystallinen Grundgebirges im Spessart. *Abh. Groszherzogl. hessischen Geol. Landenstalt*, vol. **2**, p. 190, 1891–1895.

[16] Williams, G. H. The General Relations of the Granite Rocks in the Middle Atlantic Piedmont Plateau. *15th Ann. Rept., U. S. G. S.*, p. 670 et. seq., **1895.**

which contain varying amounts of tourmaline and "flesh-colored feldspar" and in places some mica. Because of the gradation of these quartz bodies into pegmatites a different origin is assigned to them than to pegmatites showing no such gradation.

Van Hise[17] described a series of pegmatites in the Black Hills which grade into quartz veins. Pegmatitic quartz—feldspar dikes extend out into the surrounding crystalline schist; with distance the dikes exhibit banding and comb structure and finally the feldspar entirely disappears and the dike or vein consists of ordinary quartz.

In the Yukon district, Alaska,[18] there are quartz veins which grade into aplite dikes in both composition and structure. In a single outcrop the aplite is described as "changing to a vein composed of quartz and feldspar, and this by disappearance into one of quartz alone." The same author further notes (p. 230) pegmatites grading into quartz veins by the quartz first becoming segregated in the center with the feldspar along the walls. The feldspars then gradually disappear, leaving a vein composed of coarsely crystallized interlocking quartz with a little magnetite and pyrite and "some calcite veining which is probably secondary."

Cross[19] remarked that in the Silver Cliff District, Colorado, pegmatite dikes in places became so rich in quartz as to be practically quartz veins. Crosby and Fuller[20] recognize a gradation between pegmatites and pure quartz veins.

On the North Shore of Long Island Sound "pegmatites are abundantly developed in connection with granites and all grades are shown ranging to practically pure quartz."[21] Kemp further believes that the huge quartz vein 1000 feet in width at Lantern Hill, Mystic, Connecticut, belongs in the pegmatitic series. Holland[22] describes two large masses of white quartz on the southern face of the

[17] Van Hise, C. R., Principles of Pre-Cambrian North American Geology. *16th Ann. Rept., U. S. G. S.*, pt. **1**, p. 688, 1896.

[18] Spurr, J., Geology of the Yukon Gold District, Alaska. *18th Ann. Report, U. S. G. S.*, pt. **3**, p. 147, 1896–1897.

[19] Cross, W., Geology of Silver Cliff and Rosita Hills, Colorado. *17th Ann. Rept., U. S. G. S.*, pt. **2**, p. 279, 1896.

[20] Crosby, W. O. and Fuller, M. L., Origin of Pegmatites. *Amer. Geol.*, p. 150, **1897**.

[21] Kemp, J. F., The Rôle of the Igneous Rocks in the Formation of Veins. *Trans. Amer. Inst. Min. Eng.*, vol. **31**, p. 182, 1901.

[22] Holland, T. H., Geology of the Neighborhood of Salem. *Mem. Geol. Surv. India*, vol. **30**, p. 137, 1901.

Shevaroy hills in the neighborhood of Salem, India. The rock consists wholly of quartz in coarse interlocking crystals in places clear and transparent but generally clouded by innumerable liquid inclusions thought to be carbon dioxide. The general association of such quartz masses with peridotite intrusions throughout southern India is remarked on and a genetical relation between the two is suggested.

At Foxdale, Isle of Man,[23] quartz bodies up to 30 feet wide cut granite and surrounding schist and slates. Some have been traced a mile. They are composed essentially of quartz including both clear and opaque varieties, the latter containing liquid inclusions. Locally the quartz masses change to pegmatites by the appearance of feldspar and because of this gradation the quartz masses are looked upon as igneous dikes.

Reed[24] notes pegmatite dikes two to forty feet in width which have quartz veins associated with them. Copper has been found in them and an interesting feature of the quartz bodies is the presence within them of fine crystals of spinel which contain abundant quartz inclusions.

Referring to the Encampment District, Wyoming, Spencer[25] states that "bodies of the rock composed of feldspar and quartz and having the form of dikes were found to pass by gradation into quartz veins, a fact which suggests that they may not be true igneous intrusions in the same sense as the gabbro dikes, but rather that they formed through aqueo-igneous activity, an origin to which many pegmatites have been assigned." Klemm[26] described pure quartz masses in granites and surrounding sediments which in places show a pegmatitic gradation by the presence of random feldspar particles and some mica along the contact.

Ogilvie noted the complete gradation between pegmatites and quartz veins in the Paradox Lake Quadrangle, New York.[27] In the

[23] Lomas, J., Quartz dikes near Foxdale, Isle of Man. *Geol. Mag.*, New Series, Decade 4, vol. **10**, pp. 34–36, 1903.

[24] Reed, T. T., Nodular bearing Schists near Pearl, Colorado. *Jour. Geol.*, vol. **11**, p. 493, 1903.

[25] Spencer, A. C., Ore Deposits of Encampment District, Wyoming. *U. S. G. S., P. P.* **25**, p., 41, 1904.

[26] Klemm, G., Über der Gneisse und Schiefer der Tessiner Alpen. *Sitzungsberichte der Königlich Preussichen Akademice der Wissenschaft*, p. 56, **1904.**

[27] Ogilvie, L. H., Paradox Lake Quadrangle, New York. *New York State Mus., Bull.* **96**, 1905.

Georgetown Area, Colorado, Spurr and Garrey[28] observed the common transition of pegmatites into quartz veins. Spurr in the Southern Klondike District, Nevada,[29] found granite dikes that pass by transition into masses and veinlets of pure quartz. With reference to the Silver Peak Quadrangle, Nevada, he makes the following observation:[30] "The typical quartz and typical alaskite form two ends of a rock series between which there is every gradation. Every vein or lens thus far mined or prospected shows in places, mixed with the quartz, considerable feldspar, though in general it is found that with the incoming of the feldspar in the ore body the values fall off quickly." In the Cripple Creek district,[31] pegmatite dikes composed of quartz, microcline, muscovite and a little magnetite occasionally become so rich in quartz that they "may be mistaken for quartz veins." Prospecting showed them to be barren. J. Cornet[32] describes a transition between pure quartz veins and pegmatitic rocks.

Graton observed in Shasta County, California,[33] that "in connection with the quartz diorite occur sparingly pegmatitic dikes of rather irregular form and somewhat more acidic character than the parent quartz diorite; these pegmatites in places pass over into siliceous masses that are virtually quartz veins and carry sulfides." Erdsmannsdörfer[34] described lens-like quartz masses, occurring in most places parallel to the structure, which grade into granite or true pegmatite by the incoming of feldspar.

The Eskdale granite of the English Lake District has a markedly quartz-rich border facies.[35] The granite occurs in two roughly elliptical exposures, one with major dimensions of 12 miles and 4 miles

[28] Spurr, J. E. and Garrey, G. H., Preliminary Report on the Ore Deposits in the Georgetown Colorado Mining District. *U. S. G. S., Bull.* **260**, p. 104, 1905.

[29] Spurr, J. E., Southern Klondike District, Nevada. *Econ. Geol., vol.* **1**, p. 370, 1906.

[30] Spurr, J. E., Ore Deposits of the Silver Peak Quadrangle, Nevada. *U. S. G. S. P. P.*, **55**, p. 44, 1906.

[31] Lindgren, Waldemar and Ransome, F. L., Geology and Gold Resources of the Cripple Creek District, Colorado. *U. S. G. S., P. P.* **54**, p. 43, 1906.

[32] Cornet, J., Sur l'origine granitque de certains filons quarteux de la region metamorphique de Bastogne. *Bull. Soc. Belge de Geologie*, Tome **22**, pp. 305–307, 1908.

[33] Graton, L. C., The Occurrence of Copper in Shasta County, Cal. *U. S. G. S., Bull.* **430-b**, p. 86, 1909.

[34] Erdsmannsdörfer, O. H., Die Eckergneiss im Harz. *Jahrb. d. k. Preusz. Geol. L.-A. und Bergak.*, vol. **30**, pt. 1, p. 329, 1909.

[35] Dwerryhouse, A. R., Intrusive Rocks in the Neighborhood of Eskdale. *Q. J. G. S.*, **LXV**, p. 64, 1909.

and the other considerably smaller. The normal granite is composed of quartz, orthoclase and oligoclase, crystallized separately or in perthitic intergrowth, muscovite, and biotite. Perthite is the most common feldspar constituent. Muscovite predominates over biotite except locally. Analyses of the normal granite yield from 71.86 to 76.43 per cent silica. The width of the quartz zone is not made clear. In this zone there appears in general to be a gradual increase in quartz towards the border of the granite. Also the rock becomes finer grained. Most specimens contain in addition to quartz small amounts of one or more of the normal constituents of the granite, namely; orthoclase, oligoclase, perthite, muscovite, and biotite. Some of the extremely quartz-rich specimens contain only muscovite in addition to the quartz. An analyses of one of these yields 96.16 per cent silica. This is thought to be extreme. In the neighborhood of 90 per cent is thought by the author cited to be the amount in most places. As an explanation of the acidic border zone, Dwerryhouse suggests that the magma which on consolidation formed the Eskdale granite was more siliceous than some eutectic "probably that of quartz and orthoclase" and as a result quartz separated out early and segregated along the walls until the eutectic proportions were reached.

Bastin described quartz veins associated with pegmatites at Paris, Maine.[36] Veins of this type commonly contain small amounts of orthoclase, microcline, muscovite and black tourmaline. In some of the veins, black tourmaline is associated with quartz alone. A quartz vein containing feldspar crystals and traversing a pegmatite but with a coarsely interlocking crystallization between vein and wall is described from Boothbay Harbour, Maine. Bastin further noted the tendency in some pegmatites for the quartz to be segregated in the center with feldspar adjoining the walls. A somewhat Similar relation was found at Quincy, Massachusetts[37] where coarse-grained quartz forms the center of a cylindrical pegmatite mass.

Along the margins of the Bushveldt granite in Western Secucuniland, South Africa,[38] there are highly quartzose rocks of which

[36] Bastin, E. S., The Geology of Pegmatites and Associated Rocks of Maine. *U. S. G. S., Bull.* **445**, pp. 19 and 26, 1911.

[37] Warren, C. H. and Palache, C., *Proc. Am. Acad. Arts & Sci.*, vol. **47**, p. 130, 1910.

[38] Hall, A. L., Note on certain wide-spread Ultra-acid Rocks occurring along the margin of the Bushveldt Granite in Western Secucuniland. *Trans. Geol. Soc., S. A.*, vol. **13**, p. 10, 1911.

some are facies of granite. The ultra acid rock occurs as a narrow band as much as 2 miles wide with a total length of outcrop in Eastern Transvaal of 70 miles and covering an area of at least 60 square miles. It has considerable resemblance to a quartzite but according to the author its igneous nature is evident from the study of a large number of outcrops. The rocks are nearly always fresh and composed almost solely of quartz grains with small scattered flakes of muscovite and biotite. In places are complete gradations between the quartzose rock and varieties rich in "milky-white, flesh-colored orthoclase with clearly defined cleavage faces." Analyses are given of three specimens collected from outcrops 32 miles apart. They show the following percentages of quartz: 97.43%, 97.15% and 72.15%, with the remainder composed of muscovite, biotite, magnetite, orthoclase, rutile, and ilmenite. It is believed that this ultra-acid rock is one of the differentiation products of the magma from which was derived the granite and norite of the Bushveldt complex.

Lahee[39] described pegmatites composed chiefly of microcline, microperthite, graphic granite and quartz, a little orthoclase, acid plagioclase and muscovite. Biotite and garnet may also be present. Many of these grade into quartz veins which are described as consisting of milky or creamy quartz, in places small quantities of feldspar, generally near the margins of veins and locally a "little chlorite, muscovite, sericite, pyrite, etc." Miarolitic cavities are occasionally seen but as a rule the quartz is massive and comb structure was not recorded. Many of the pegmatites show a progressive increase in quartz away from their point of origin.

Washington gives an analysis of arizonite, described as a quartz dike rock, which yields 92.59 per cent silica. An unpublished reference to Spurr and Washington is given in connection with the analysis.[40]

The Pelham granite gneiss[41] at its contact passes by gradual transition, structurally and mineralogically into a quartz rock which at Crag Mountain in Northfield becomes over 300 feet thick. This rock

[39] Lahee, F. H., Relations of the Degree of Metamorphism to Geological Structure and to Acid Igneous Intrusions in the Narragansett Basin, Rhode Island. *Amer. Jour. Sci.*, Vol. **33**, pp. 456–461, 1912.

[40] Washington, H. S. Chemical Analyses of Igneous Rocks. *U. S. G. S.*, *Prof. P.* **99**, p. 50, 1917.

[41] Emerson, B. K., Northfieldite, Pegmatite and Pegmatite Schist. *Amer. Jour. Sci.*, vol. **40**, pp. 212–217, 1919.

is called northfieldite by the author cited, to whom its occurrence suggests that it represents "an original ultra-acid contact differentiate and deposit of the magma." Two varieties of the rock are distinguished. At Crag Mountain, the mass suggested a pegmatite without feldspar and is made up of bands about 1 inch thick, conformable with the bands of the Pelham gneiss, made up of coarse quartz and random flakes of muscovite. Microscopically it is composed of large unstrained quartz grains in places containing blebs of quartz of different orientation from the host, a few particles of muscovite, tourmaline, zircon, negative quartz cavities and large motionless bubbles. Gradations of pegmatite into the northfieldite were observed. The other type of northfieldite at Mount Orient in Pelham, "has the aspect of a slightly actinolitic or biotitic quartzite or an extremely quartzose aplite. Biotite for the most part, garnet, zircon, rutile, and a little feldspar were noted. Actinolite and tremolite thought to be the result of contamination by limestone, are prevalent in some localities."

Billingsley found that in the Montana batholith,[42] where the more acid phases form the contact, there is a gradual increase in acidity in the outlying dikes and sills of the igneous rock. "These, with crystalline continuity, grade from normal granite at the point of departure from the parent mass to alaskite and even pure quartz at their further termination."

Miller[43] described numerous gradations of pegmatite and aplite into quartz masses called by him, silexite. Two ages of granite pegmatite are distinguished, early segregation masses and later more dike-like masses. Both grade into quartz masses. The pegmatites are simple in composition, being made up largely or wholly of pink or white feldspar and quartz. Among the minerals specifically mentioned in descriptions, there may be listed microcline, microperthite, oligoclase, biotite, apatite, zircon, magnetite, hornblende, and pyroxene. The last three minerals are believed to be largely or wholly the result of contamination by the old dark gneisses and gabbro invaded by the granite. Gradations to the quartz masses are brought about by the gradual elimination of the feldspar. In North Creek Quadrangle, a body of gabbro pegmatite six feet wide is observed to grade into a mass of "practically pure silica (silexite)

[42] Billingsley, Paul, The Boulder Batholith of Montana. *Trans. Amer. Inst. Min. and Met. Eng.*, vol. 51, p. 43, 1915.

[43] Miller, W. J., Pegmatite, Silexite, and Aplite of Northern New York. *Jour. Geol.*, vol. 27, pp. 27–54, 1919.

four feet long." The gabbro pegmatites are described as consisting chiefly of potash feldspar and quartz, but with plagioclase important in some cases, muscovite and black tourmaline usually present, and biotite and hornblende not rare. Granite aplites composed of "white or light grey potash feldspar, microperthite and quartz were observed grading into quartz masses."

Pegmatitic gold quartz veins are found in the Pack Valley district of Raft River range and Spring Creek district of Deep Creek range.[44] In both districts, the veins extend from the intrusive into the adjacent quartzite with ore being found in the veins in both granite and quartzite. "Typical gangue of the ore-shoots is rather fine grained, vuggy quartz containing sulfides and arsenides in small amounts in the primary ore." The finer vuggy quartz gives place along the dip or strike or from the middle toward the wall to coarse pegmatite quartz which in turn grades into a mixture of quartz and feldspar. In one vein there is some indication that feldspathic material decreases and quartz and sulfides increase with increasing distance from the granitic rock. Many gradations between pegmatite, aplite and quartz masses have been observed in north central Idaho.[45]

Brown notes with regard to the quartz veins and pegmatites at Ashland, Alabama,[46] that all gradations may be found between pure quartz veins and veins of nearly pure coarse feldspar.

Baumgärtel appended to his article on intrusive quartz masses[47] a few examples in the literature of quartz masses showing an evident genetic relation to igneous rocks; these he discusses briefly. Among the references cited a few are not available to the present writer. However, no new point appears to be brought out in them and they only serve to emphasize the wide distribution and common occurrence of the gradational relation between igneous bodies and masses consisting almost wholly of quartz. These references are incorporated in the bibliography at the end of this paper.

It seems, then, from the observational evidence available in the literature it must be taken as proved that quartz masses grade into pegmatites, aplites or like rocks which in turn grade into typical

[44] Butler, B. S., The Ore Deposits of Utah. *U. S. G. S., P. P.* **111**, p. 159, 1920.

[45] Thomson, F. A. and Ballard, S. M., Geology and Gold Resources of North Central Idaho. *Idaho Bur. of Mines and Geol., Bull.* **7**, p. 41, 1924.

[46] Brown, J. S., Graphite Deposits of Ashland, Alabama. *Ec. Geol.*, vol. **22**, p. 224, 1925.

[47] Baumgärtel, B., *Zeit. d. deut. geol. Ges.*, vol. **63**, p. 228, 1911.

igneous rocks. But in arriving at this conclusion we have not in any way determined if any of the quartz masses represent the solidification of an igneous magma; from the meagre descriptive details of the actual relations given, it seems impossible to form any conclusions on this matter.

Supposed Igneous Quartz Masses not Grading into Igneous Rocks

Goldschmidt[48] described from the Stavanger district large masses of quartz rich rock which are regarded as the last and most acid differentiation product of the Opdalit-Trondjemite magma. These masses are typically laccolithic in shape and consist of even granular quartz with scattered porphyritic crystals of microperthite and very small amounts of rutile, zircon, carbonate, muscovite, and chlorite. On Goldschmidt's map they are shown to be up to 350 feet in diameter.

An analysis of this rock gave 95.35 per cent of silica. The mineral composition calculated from the analysis is as follows. It is said to agree well with the observed mineral composition.

Quartz	90.0	per cent.
K-Feldspar	5.6	"
Albite	2.2	"
Muscovite	0.3	"
Chlorite	0.03	"
Iron Oxide	1.4	"
Rutile	0.003	"
Apatite	0.05	"
Calcite	0.30	"
	100.00	per cent.

In Vogtland at the western part of the Erzegebirge[49] a granite massif is found intruding Cambrian slates. A considerable area of hornfels is present in the vicinity of the intrusion. The granite outcrops in small boss-like bodies in the hornfels area—the inference being that the granite is nowhere far beneath the surface in the contact metamorphic region and that the granite masses represent cupolas. The hornfels is a compact dark rock in which individuals of cordierite are visible, giving the rock a porphyritic appearance.

[48] Goldschmidt. U. M., Die Injektionmetamorphose im Stavanger Gebiete. *Videnskapsselskapets-Skrifter*, **1920**, No. 10, p. 31.

[49] Baumgärtel, B., *Zeit. d. deut. geol. Ges.* vol., **63**, p. 175. 1911.

The microscope shows that in addition to cordierite there are quartz, muscovite, biotite, magnetite, tourmaline, zircon, calcite, rutile, and carbonaceous material.

The hornfels and also the unaltered slate farther out are traversed by many lenses of quartz ranging up to 20 centimeters in width which tend to follow the schistosity but which in places cut across. The lenses are of two types. One, the younger, generally consists of pure quartz but in places contains a little cordierite, chlorite, apatite, pyrite, chalcopyrite and considerable calcite. The cordierite and chlorite, when present, are largely restricted to the walls, whereas the calcite tends to be confined to the center of the body. A slight tendency to crustification was noted in places. The second type is characterized by larger grains of quartz which commonly showed cataclastic structure, and also a great number of carbonic acid inclusions. These veins are cut by those of the other type. Some of them also show the presence of considerable of the quartz characteristic of the first type which had evidently been deposited after the older quartz had been deformed. In the older quartz veins, the microscope reveals apatite, spinel, corundum, magnetite, rutile, garnet, chalcopyrite, plagioclase, albite, oligoclase, andesine, and some orthoclase and microperthite.

Within the contact zone it was noted that the older quartz lenses had exerted a contact affect in addition to, and super-imposed upon, that of the granites. This took the form of a marked increase in the size of the grain of the material adjoining the quartz masses, also by the introduction of garnet; wolframite and scheelite were also noted. This phenomena appears to have been quite marked. Although the same quartz lenses extend out into the clay slates, the rock adjoining the lenses was not here affected.

As interpreted by Baumgärtel, the above facts indicate that the older quartz lenses exerted a further contact metamorphic effect which was super-imposed on that exerted by the granite. These lenses are thought to be genetically associated with the granite, and are considered to represent a slightly later phase of the intrusion. The common origin of the quartz of the lenses and that of the granite is indicated by their similarity, including the common presence of inclusions of carbonic acid. That the quartz lenses exerted no affect on unaltered slate adjoining the contact metamorphic aureole is thought to be due to the slates not being hot enough at the time of the quartz intrusion—the quartz masses

were only able to exert contact metamorphism where the granite massif had already raised the temperature of the rocks. The younger quartz lenses represent a later and real hydrothermal phase, their lower temperature and different character being indicated by the complete absence of contact metamorphic affects and by quartz free from carbonic acid inclusions, as well as by other features of mineral composition.

Discussion

The present writer is of the opinion that the apparent contact metamorphism exerted by the quartz lenses as described by Baumgärtel, is a strong indication that they represent solidified magmatic material, but that the evidence is not wholly conclusive. If the quartz lenses had exerted contact metamorphism outside of the area metamorphosed by the granite, the evidence would have been unimpeachable. Normal contact metamorphism is a phenomena caused typically only by igneous rocks. In the case under discussion, however, it is thought probable that a hydrothermal solution, on emanating from the parent solidifying magma, would carry sufficient heat, which, coupled with the effect of accompanying gases would increase the molecular activity in the material adjoining the vein to such an extent as to cause the additional metamorphism. No great amount of additional heat, or of other contact metamorphic factors, would be required to merely accentuate the phenomena due to the granite mass. The character of the quartz, whether of the α or β modification was not determined.

Rock magmas have different temperatures of consolidation, depending on their composition. It would be expected also that hydrothermal solutions on emanation from a consolidating magma would have various temperatures depending, among other factors, on the composition and temperature of the parent magma, and on the composition of the solution itself. The temperature at which the different constituents of the solution would be deposited would depend on their composition and their relative concentration in the solution. The temperature of formation of a mineral, either deposited from a solution or representing the constituent of a solidified melt, is such a variable factor that the determination of the temperature of formation of a mineral present in a quartz body has little diagnostic value in determining whether the quartz mass represents high temperature vein material or an igneous rock. A

mineral might under one set of physical conditions form as a primary constituent of an igneous rock at a lower temperature than it would be deposited from a hydrothermal solution under another set of conditions. Of course, if there is an evident association between the quartz mass and igneous rock, the igneous rock had a higher temperature of formation than the later quartz masses. Inasmuch as there is a gradation from quartzose igneous rocks into hydrothermal veins, the determination of the temperature of formation of quartz at a particular place in the sequence would tell us little.

The question remains whether there is any mineral commonly present in quartz masses that might be of diagnostic value. The presence of perthite in the last two examples discussed and some previous ones suggests that it may be such a mineral. As far as could be determined by the writer, it does not occur as an orthodox vein mineral. Makinen[50] points out, also indicated by Warren,[51] that potassium and sodium feldspars form an isomorphous series of mix-crystals at higher temperatures. Under these conditions we get K-feldspar containing large percentages of Ab (+An) in their composition. Likewise the albite contains considerable K-feldspar. If the feldspars are formed at lower temperature, there is a formation of nearly pure K and Ab (+An) feldspar. Whether these constituents are in the form of an intergrowth or as separate crystals it is thought to depend on the rate of cooling;[52] if cooled quickly, the perthitic intergrowth will be produced; if slowly, the constituents will be completely separated. Under yet lower temperatures, are formed the purest feldspars; adularia, with little Ab (+An), and plagioclase with almost no K-feldspar. They constitute the feldspars normally found in veins.

Perthite, then, occurs normally, not as a vein mineral but as a pegmatite feldspar.[53] It is therefore suggested that the presence of perthite in a quartz rock is indicative of an igneous origin.

Even if the diagnostic value of the presence of perthite is granted, the problem still remains as to the origin of quartz masses in which

[50] Makinen, E., Über die Alkalifeldspate. *Geol. Fören, Förhandl.*, bd. **39**, p. 121, 1917.

[51] Warren, C. H., A Quantitative study of Certain Perthitic Feldspars. *Proc. Am. Ac. Arts and Sci.*, vol. **51**, No. 3, p. 145, 1915.

[52] Warren, C. H., *Op. cit.*, p. 154.

[53] Makinen, E., *Op. cit.*, p. 134.

perthite is absent. No other minerals of common occurrence in quartz masses suggest themselves to the writer which would be of diagnostic value in this regard.

Conclusion

According to the prevailing theory as to the operation of magmatic differentiation, a gradation with increasing quartz from typical igneous rock into quartz veins of undoubted hydrothermal origin would be expected. Gradation from alaskites, pegmatites, or aplites and practically pure quartz masses have been so frequently alluded to in the literature that there is no doubt as to their occurrence. This, however, does little more than prove their genetic association.

As the gradation between igneous rocks and hydrothermal veins is represented, in some places at least, by highly quartzose material, it is believed that some of the quartz-rich masses are quartz dikes. The gradational relation makes it exceedingly difficult to distinguish between quartz dikes and quartz veins.

Mineral composition may be diagnostic; it is thought inasmuch as perthite is not an orthodox vein forming mineral, its presence in a quartz mass would indicate an igneous origin.

Evidence of mode of emplacement might be indicative; quartz masses might be intruded laccolithically on a small scale, as indicated by structures formed in the intruded rock, or they might be intruded throughout their not yet entirely solidified parent mass, as is the case of the silexites of northern New York as interpreted by Miller.

Igneous metamorphism, exerted under normal conditions by a quartz mass, would be diagnostic but in the literature, there is no unimpeachable evidence that such exists.

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ULTRA-VIOLET ABSORPTION OF CERTAIN MINERALS

NORA M. MOHLER, *Smith College.*

The experiments reported here extend the information concerning the absorption of light by certain transparent minerals through the ultra-violet region to 190$\mu\mu$. Limits of this transparency have been reported for many gems by Absalom,[1] and for several varieties of colored quartz by Tsukamoto.[2] They found little or no correlation between transparencies in the visible and in the ultra-violet regions. Holden[3] gives absorption curves for several varieties of quartz, including smoky quartz and amethyst, for the visible region. These are here extended to shorter wave-lengths, and in addition curves have been obtained from two samples of agate, one of opal, and several of mica.

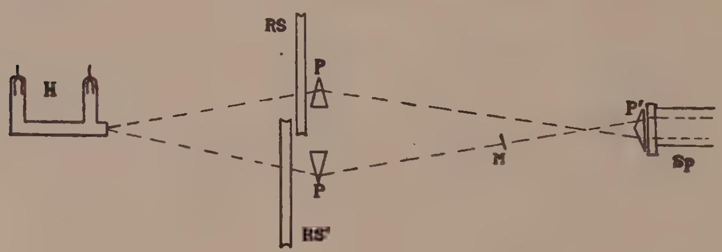


FIG. 1

H = Hydrogen discharge tube.
RS = Rotating sector, variable aperture.
RS' = Rotating sector, fixed aperture.
P, P' = Biprism.
M = Mineral section.
Sp = Spectrograph.

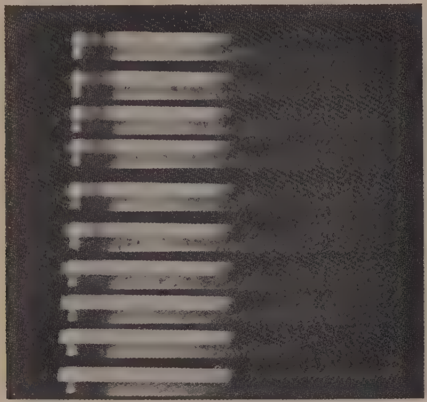
The apparatus was arranged as indicated in Fig. 1. The source of light is a hydrogen discharge tube of pyrex with heavy aluminum electrodes and a quartz end window, operated at a pressure of several mm. by a one kilowatt transformer. This gives a continuous spectrum throughout the 650$\mu\mu$ to 190$\mu\mu$ range. The

[1] H. Absalom, Ultra-violet transparency of colored media. *Philosophical Magazine*, **33**, p. 450, 1917.

[2] K. Tsukamoto, Transparency of colored quartz for the ultra-violet. *Revue d'Optique*, **6**, p. 478, 1927.

[3] E. Holden, Smoky quartz and amethyst. *Amer. Mineralogist*, **10**, p. 203, 1925.

Gaertner rotating sector photometer and quartz spectrograph are set up in the usual way. The beam of light from the lower biprism of the sector photometer passes through a thin section of the mineral to be studied before it reaches the second biprism, which is placed in front of the slit of the spectrograph. A series of photographs is then taken with different settings of the upper variable sector; the two beams from the sectors give adjacent records. If a point of equal density occurs on these records, the absorption coefficient for that wave length is given directly by the setting of the variable sector. A typical photograph is given (Fig. 2.).



Muscovite d=.018 mm.
FIG. 2

The absorption coefficient referred to is defined by the equation

$$I=I_o e^{-\mu d}$$

in which I_o = intensity of incident light.

I = intensity of transmitted light.

μd = absorption coefficient.

μ = absorption coefficient per cm.

d = thickness in cm.

Two rather dark specimens of smoky quartz gave identical curves which check for the visible region with those given by Holden.[4] The effect of the coloring material is the broad absorption

[4] Note that since Holden's graphs are of percentage of transparency and the above relationship is a logarithmic one of absorption, his curves are reversed and have much steeper slopes for the same values.

band to which the color is due and abrupt absorption at 240$\mu\mu$. The amethyst curve is from sections cut from amethyst of rather deep but not dark color. There is in addition to the absorption band in the visible region an equally distinct one at 262$\mu\mu$ and in spite of increased absorption throughout the range the limit of transparency is lowered to 220$\mu\mu$ (Fig. 3).

Only one sample of opal of the right thickness was available. By transmitted light it is of a clear yellow color. Complete absorption in the shorter wave-lengths of the visible region occurs.

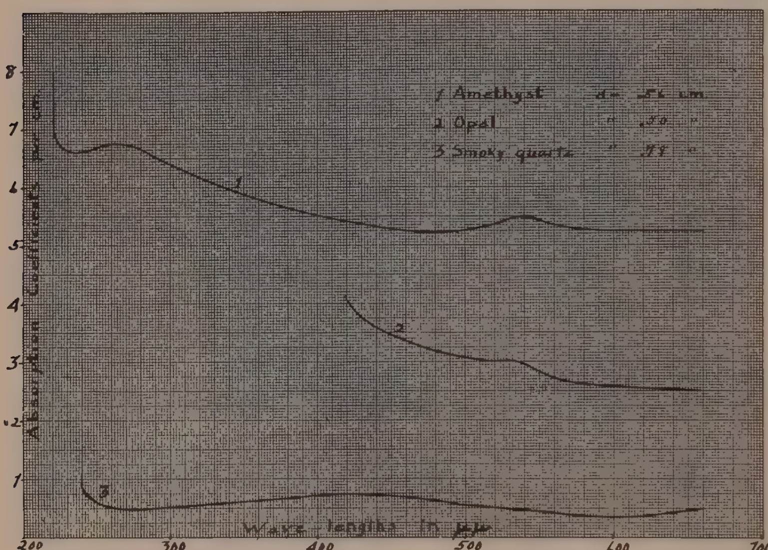


Fig. 3

The agates tried also show a considerably decreased limit of transparency which may be due to the change in structure as well as to the impurities present. Both pieces are of translucent brownish yellow, with lighter portions. From specimen 1 (Fig. 4), curve *a* was taken through a slightly milky portion, *b* through a part that was of decided yellow color. The change in shape of the curve indicates a different coloring substance rather than mere dilution. Specimen 2, of darker brown but with clearer portions than 1, gives, through one of the latter, a curve very similar to 1*b*. Absorption by the darker portion was so great that a curve could not be obtained.

The curves for biotite and muscovite are included for comparison (Fig. 5); it was of course simple to extend the values to higher values of μ since d could be made small. For this reason

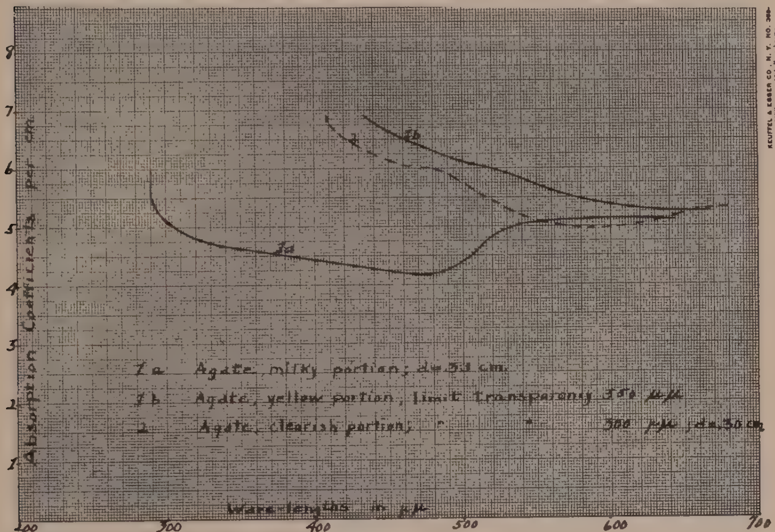


FIG. 4

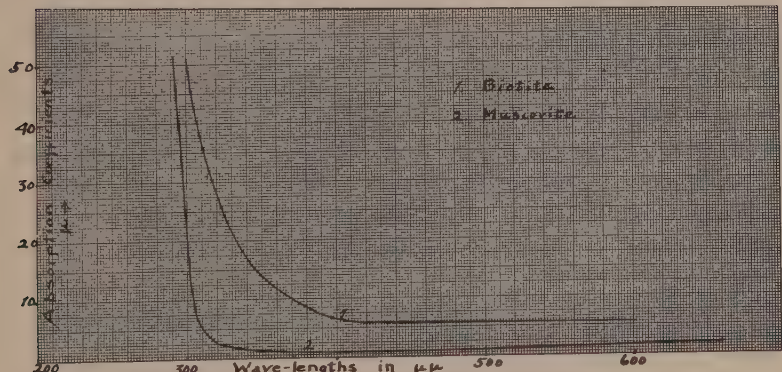


FIG. 5

points on the curves can be more easily checked and are more dependable. Faintly colored specimens of pink and green muscovite also were photographed but without significant differences.

The author wishes to express her appreciation for the assistance given in the spectroscopic work by Miss Gladys A. Anslow, and for the help given by Mr. Robert Collins and Mr. Howard Meyerhoff in the identification of specimens and for other geological assistance.

THE PHILOSOPHIC CLASSIFICATION OF MINERAL STRUCTURE*

A. C. Lane, *Tufts College.*

TABLE OF CONTENTS

Introduction

The recent new edition of Kraus and Hunt's determinative tables inspires me to submit to the Mineralogical Society, and to them and other writers of mineral text books, the question whether the terms applied to the structure, habit and grain of minerals can be treated in a philosophic fashion so as to bring out their connection on the one hand, with the power of crystallization and with fundamental properties connected with the arrangement of the atomic network, and on the other hand, with the arrangement and frequency of the centers of crystallization. Though they do not depend wholly upon these factors and it is with diffidence that I present this tabulation for consideration, such a classification may make the terms seem more reasonable, interesting and important to the student and easier to remember, and of interest because of their indication of the surroundings not merely in determinative mineralogy but in genetic mineralogy as well. This merges into geology and the theory of ore deposits. The field of the habit of crystals has been developed more in Europe than in America and is perhaps worthy of more attention here.

* Presented at the annual meeting of the Mineralogical Society of America, Toronto, December 30, 1930.

II. Degree of Dominance of Direction Dependent Upon Temperature and Rate of Formation

Generally speaking, the degree of apparent dominance of certain directions is inverse to the temperature and the slowness of formation. The higher the temperature, the less dominant is any one direction. Also, the slower the formation, the more the crystal approaches a polyhedron inscribed in a sphere. We can see a reason for this, because if the atoms which are added to a crystal drift in only slowly from outside, the forces and the direction of attraction from within a crystal will have much less importance than as though there were a large abundance of material to be put into shape. It will be only putting into a general law what Tammann found experimentally when he found that only one or two degrees below the melting point he had larger crystals with more numerous faces and less oriented axes than when the crystals were formed farther below the melting point.[1] This is, of course, not absolutely true, and the rule given above has exceptions. For instance, prismatic topaz has basal cleavage. I think, however, that in the study of the habit and structure of crystals, such as that of J. G. Koenigsberger on the crystals of Switzerland there are a good many facts that may be brought into line. As Koenigsberger says:[2] "It is a frequent peculiarity that the lower the temperature of formation of a crystal is, the more is it stretched in a dominant direction," and as he says[3] "feebler kinetic (thermal) energy of the crystal lattice allows the differences of attraction in different directions to have more weight than when there are greater thermal oscillations of the atoms or atom groups."

For instance, in silica the less symmetrical quartz is prismatic in veins and stable below 575°. The shorter bipyramidal quartz such as the phenocrysts of quartz in quartz porphyry is stable from 575° to 875° and is more symmetrical. Tridymite is hexagonal and stable above 875° and the isometric cristobalite is formed at the highest temperature. The pyroxene of the basic rocks is short and in the large ophitic patches almost equi-dimensional. Salite is more prismatic. The hornblende is usually more elongated with a bet-

[1] G. Tammann, *Kristallisieren und Schmelzen*, **1903**, p. 134.

[2] *Fortschritte der Mineralogie, Kristallographie und Petrographie*, **11** (1927) p. 11.

[3] Ueber alpine Minerallagerstätten. Mineralklüfte und Differentiation ihrer Paragenese. *Schweiz. Mineralog. u. Petrogr. Mitteillungen*, **V** (1925), pp. 66 to 127, the quotation is from p. 127.

ter cleavage and I presume is formed at a lower temperature, especially in the schists, and the tremolite and asbestos possibly at lower temperatures still. Pyrite is isometric and more of a high temperature mineral than marcasite. Leucite is more of a high temperature mineral than orthoclase and is at high temperatures isometric. The igneous rocks generally are rocks formed at higher temperatures than the metamorphic rocks which are characterized by minerals in which there is a pronounced tendency to a direction of growth which determines the schistosity. It is also well known that slow formation and large crystals have modifications and complications tending to round off the forms. Small crystals are simple. The large masses of feldspar in a pegmatite show little dominant direction as compared with the trichitic feldspar of a basalt near the margin. Other factors, such as the character of the solution from which crystals form, and the curious orienting effect of other minerals, by which, for instance, flattened out and distorted hard tourmaline crystals occur parallel to the cleavage of the soft mica, seem more local and individual, though well worthy of attention. But they are not available as yet in classification.

I take it that the large nearly equidimensional highly modified crystals of calcite in the Lake Superior copper country are produced by relatively slow crystallization at relatively high temperatures and Koenigsberger says that in the Alps the lower the temperature of its formation, the more prismatic the calcite tends to be.

III. Effect of Dominant Directions on Structure

When there are dominant directions, they may be classed as follows:

A. Dominant direction is that of greatest growth, in general that of greatest attraction and prismatic cleavage.

The prisms when fine and tough may be called fibrous, or if ductile, filiform, when brittle, acicular.[4] The luster may be silky. When the centers of crystallization are relatively rare, we are likely to have radiated structures and these may make spherules, or if the centers are scattered over a surface, as along a crack, stellate. An aggregate of non-radiating spherules may give, if small

[4] I find that for some brittleness is not a part of the connotation of the word acicular, but rather straightness. The minerals we denote as acicular are, however, much the same. There are many such points for mineralogists to consider.

as shad roe, an oolitic or, if like peas, pisolitic or spherulitic structure, or globular or orbicular, in order of size. If the spherules, interfering, give clustered rounded surfaces, they may give a structure like grapes which is called botryoidal, if larger, reniform, "kidneys" or mammillary structure.

B. Dominant direction may be that of least attraction and at right angles to it will be the greater growth. The mineral is then tabular, or if tough and flexible, foliated, and the luster is likely to be pearly on the surface. If highly tabular, it may be lamellar, or (especially if tough) foliated and micaceous.

C. Not infrequently the direction of greatest and of least attraction are both more or less dominant. Then we have it both elongated and flattened like laths, each cleaving in a structure known as bladed. If the centers of crystallization are relatively scarce, if arranged along a line, we may have the plumose structure; or the milled edge or sheaf of wheat structure of stilbite, prehnite, and calamine.

If centers are abundant in a solid mass of basaltic lava, we have the diabasic structure of feldspar "divergent strahlig."

D. If there are three dominant directions, which are practically all equal and not at right angles, the crystal approaches equidimensionality and it is very likely to be isometric. The cleavages may be three, (rhombohedral if not at right angles, cubic, if they are); or four (octahedral); or six (dodecahedral); and we have minerals like calcite which may be classed as tabular in some occurrence, prismatic in others, depending on the temperature and composition of the solution from which it crystallizes.

E. There are certain structures where the direction of growth of the individual crystal is not conspicuous.

The dendritic or arborescent are tree-like forms branching from sparse centers of crystallization without regard to dominant crystal directions, though at times branching is crystalline.

In the reticulated form the crystals are arranged in more of a network in the plane, and they are usually prismatic.

IV. Structures Dependent on Arrangement of Centers of Crystallization

A. Centers of crystallization float (Schwebend). This gives the structure of the phenocryst and porphyries and also of the porphyroblasts such as staurolite and garnet in schists. Besides these,

we also have, however, certain diagenetic crystals like the crystals of gypsum and the hopper shaped crystals of salt which sometimes occur in shales.

B. Centers of crystallization extremely sparse (Punktformig). This might apply to the rarer minerals of the pegmatites and is pretty nearly what is meant by disseminated or sparsely disseminated.

C. Centers of crystallization scattered on a thin crack.

1. If combined with a radiated structure, we have a stellate appearance as in wavellite.

2. If there is growth out in tree-like form from these centers, we have the dendritic form.

D. Centers of crystallization scattered on surface. We have the botryoidal, reniform, or mammillary structures above mentioned.

E. Crystallization growing in from the surface of the cavity. This is the drusy structure, when they differ from the wall rock, miarolitic when they are the minerals of the rock.

F. Crystallization centers scattered abundantly through the solid gives a granular structure: fine grained texture when less than a mm. apart; medium grained when one mm. to a cm.; coarse when over a cm.

NOTES AND NEWS

A NEW OCCURRENCE OF SYNGENITE

Ruth Doggett Terzaghi, *Radcliffe College.*

Syngenite, ($CaSO_4 \cdot K_2SO_4 \cdot H_2O$), has previously been described only from salt deposits in association with halite, gypsum and anhydrite. I have recently identified as syngenite the mineral which appears to comprise over 99% of a fine white powder, whose maximum grain size is 0.3 mm., collected in 1902 by Whitman Cross on the island of Maui, Hawaiian Islands. One portion of the powder was designated "Crater of Haleakala. Incrustation on lava with solid crust"; another bears the label: "Haleakala. In the 'cave' used as retreat."

Qualitative tests showed the powder to be a hydrous potassium calcium sulphate.

The identification was made on the basis of the composition and of the following properties determined on the larger grains: good prismatic cleavage, twinning not infrequent, parallel (100); $c \wedge X = 4° \pm 2°$, 2V (estimated) 25°, $\rho < \nu$, strong. $\alpha = 1.500$, $\beta = 1.515$, $\gamma = 1.520$. These data are fairly close to the accepted values for syngenite.

In response to invitations from the Tulsa Geological Society and The American Association of Petroleum Geologists, the Council of the Geological Society of America has voted to hold the next annual meeting in Tulsa, Oklahoma, Tuesday, Wednesday and Thursday, December 29, 30 and 31, 1931. As in previous years the Mineralogical Society will hold its meetings at the same time and place.

A series of three field trips on December 28 is being arranged as follows:

(1) Spavinaw granite
(2) Cushing structure
(3) Oklahoma City oil field

A two day trip also is being offered to the Arbuckle Mountains, January 1 and 2, 1932, followed by trips to the Ouachitas and Wichitas.

Reduced railroad rates on the certificate plan of fare and a half are being arranged for the Tulsa meeting.

A report from Winnipeg, Manitoba, states that a discovery of a rich deposit of iron ore has been reported in the Steep Rock Lake area near Atikokan, Ontario, on the Canadian National Railways west of Fort William. The ore is hematite and is said to be of good quality. The new discovery should not be confused with the Atikokan Rim Range which is a high sulphur magnetite. An analysis of the ore shows that it contains 65 per cent iron and 23 per cent silica with 0.03 per cent phosphorus.

The Canadian Gypsum Company, a subsidiary of the United States Gypsum Company, has purchased property at Willow Grove, south of Hamilton, Ontario, where a new vein of massive gypsum has been located, according to the Industrial Department of the Canadian National Railways. The new company will construct a plant to manufacture a full line of gypsum products.

A news item from Toronto, Canada, states that a government assay of ore from the pitch-blende deposits in the Great Bear Lake district of the Northwest Territories indicates the possibility of this area being rich in radium-bearing ore of a commercial character. The government tests which were made on two samples showed 144.51 and 162.39 milligrams, respectively, of radium per ton. So far, the known deposit consists of two veins, one about 2000 feet long and varying in width from 5 to 20 feet, and the other of about 700 feet in length and varying from 6 to 10 feet in width. Within the veins are outcroppings of pitch-blende ore from 2 to 9 inches in width running with the vein.

The value of Canada's mineral production in 1930 amounted to $276,865,000. The thirteen leading mineral products were: Coal $53,000,000; gold $43,199,000; copper $38,687,000; nickel $24,449,000; cement $17,686,000; sand, gravel and stone $16,500,000; lead $12,992,000; clay products $11,000,000; natural gas $10,561,000; silver $10,057,000; zinc $9,393,000; asbestos $8,600,000; and petroleum $5,120,000.

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, May 7, 1931

A stated meeting of the Philadelphia Mineralogical Society was held on the above date, Mr. Biernbaum presiding. There were 53 persons in attendance including 40 members. Mr. Cienkowski outlined the chief features of the Junior mineralogical exhibit to be held at the Northeast High School on the evening of May 20.

Mr. Frank Hartman addressed the Society on *Radium and Radium Products.* Introductory to an unusual exhibition of radioactive material, Mr. Hartman paid high tribute to the Fluorescence Exhibit placed in the mineral hall of the Academy by Mr. Gordon. "No other such exhibit compares with this one anywhere in the world." Various paintings which had been painted with activated zinc sulfide and other fluorescent materials were exposed for a few seconds to a lamp, then displayed in the darkened room, which produced a striking example of fluorescence.

The ordinary manifestations of radioactivity were demonstrated with an electrometer and spinthariscope. The differences between alpha, beta, and gamma rays were pointed out. Many practical points concerning the handling of radium and the various uses of radium products were described.

Mr. Cienkowski reported on a trip taken with four junior members to the following localities: Easton, Pa.; Little Falls, Diamond Hill, and Bedford, N. Y.; and Paterson, N. J. Mr. Vanartsdalen reported epidote in quartz and silicified wood in a quarry at Holland Station. Mr. Peterson reported a large beryl crystal from Blue Hill, Pa.

After a vote of thanks to Mr. Hartman for his talk and numerous demonstrations, the meeting adjourned.

LESTER W. STROCK, *Secretary*

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND

MINERALOGICAL SOCIETY, *March 17.*—SIR JOHN S. FLETT, President, in the chair. — MR. A. J. P. MARTIN: *On a new method of detecting pyro-electricity.* On changing the temperature of certain crystals electric poles of opposite sign are developed at the two ends. In these experiments the temperature change is produced by cooling in liquid air and the electric charge is detected in the following way. The crystal is suspended by a long thin glass fibre near to the copper plate which may be moved near to or away from the crystal, both of them being immersed in the liquid air. The charge on the crystal induces an equal and opposite charge on the plate and the attraction between the two causes the crystal to move nearer the plate. This method is specially suited to very small crystals or to those which are decomposed on heating.

DR. D. R. GRANTHAM and MR. FRANK OATES: *On the Mbosi meteoric iron, Tanganyika Territory.* A wedge-shaped mass of meteoric iron measuring $10\times4\times3$ feet and estimated to weigh 12 to 15 tons was found late in 1930 near Mbosi between Lakes Tanganyika and Nyasa. It is a medium octahedral containing 8.69 per cent of nickel.

Mr. S. R. Nockolds: *On the Dhoon (Isle of Man) granite: a study of contamination.* The Dhoon granite forms a small boss-like mass intruded into the Lonan Flags. Two main types are present, one of which is slightly earlier in date than the other. The difference between the two types is mainly textural. The main type may be termed biotite-granodiorite-porphyry whilst the other is a biotite-granodiorite. Both types are abnormal in that the biotite occurs in clots and in association with zoisite, ilmenite (usually with a border of granular sphene), sphene itself and, more rarely, epidote, clinozoisite and garnet. These clots represent the last remnants of a regionally metamorphosed basic igneous rock which has been absorbed by the original granitic magma. The theoretical aspects of this contamination are discussed and it is finally concluded that the original magma was of alkali-granite type and similar to the quartz porphyry dikes which are associated with the mass. All the evidence points to an extensive interchange of oxides between the original magma and the basic igneous rock. Further it is shown that the peculiar albitization of the felspars in the "granite" of both types, is indirectly dependent on the contamination.

Mr. A. G. MacGregor: *On clouded felspars as a result of thermal metamorphism.* A special type of cloudiness in plagioclase due to the development of minute inclusions is shown to be the result of contact thermal metamorphism acting after consolidation of the igneous rock. The effects have been observed in various contact metamorphosed lavas in Scotland. Similar cloudiness is observed in the Scourie Dyke, the 'hyperites' of Sweden, malchite of Melibocus, and many other rocks. The possibility of similar clouding being produced as a deuteric effect at a late stage in consolidation is considered.

Mr. C. N. Fenner: *On the residual liquids of crystallizing magmas.* Discussion of the character of the residues left by the crystallization of magmas, and consideration of articles by F. Walker, Daly and Barth, Bowen, Schairer and Willems in which some criticism has been offered of the present author's paper on 'The Crystallization of Basalts.' In conclusion a short summary is given of outstanding points of evidence that should be taken into consideration in forming an opinion on the broad problems of differentiation.